

**METHOD OF NON-DISRUPTIVE CAPACITY SCALING FOR A DATA
STORAGE LIBRARY**

5

BACKGROUND OF THE INVENTION

1. Field of the Invention:

10 The present invention relates generally to robotic media storage library systems, and more specifically to a redundant system that includes a plurality of independent robots in the form of robotic pods.

2. Background of the Invention:

15 The current enterprise class library system contains multiple independent robots for concurrently manipulating multiple media cartridges. The library system comprises an array of media storage cells and media cartridge players. A system of rails is used to guide robotic pods through all of the locations on the array.

20 Scalable library systems typically incorporate additional robotic mechanisms and related electromagnetic hardware to increase the size of a system. Some large systems use "pass through" mechanisms to pass cartridges between individual silos to increase the capacity of the system. Pass through mechanisms are field upgradeable,
25 although the library system must be shut down to allow service personnel inside the enclosure(s) during installation. A silo is a "closed" shape that does not allow for capacity scaling without pass through.

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Therefore it would be desirable to have a method for expanding library system capacity without disrupting normal library operations.

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SUMMARY OF THE INVENTION

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5 The present invention provides a method for scaling
a media storage library, wherein the library comprises a
plurality of media storage cells and at least one media
picker robot. The method comprises connecting a new
physical component to a section of the library. Examples
of new components include additional robots, storage cell
10 arrays, media players, as well as connecting a second
adjacent library by means of a pass-through mechanism.
Control software integrates this new physical component
into the function of the library by auditing the content
and function of the new component. During the connection
15 and functional integration of the new component, the rest
of the library continues its current operations. The
method may further comprise defining at least one work
zone within the library, wherein robots do not enter the
work zone but continue to operate in other areas of the
20 library.

BRIEF DESCRIPTION OF THE DRAWINGS

5 The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in
10 conjunction with the accompanying drawings, wherein:

Figure 1 depicts a perspective pictorial diagram illustrating the architecture of a single library storage array in accordance with the present invention;

15 **Figure 2** depicts a pictorial diagram illustrating the addition of an extension array to an existing library system in accordance with the present invention;

Figure 3 depicts a flowchart illustrating the procedure for adding an extension array to an existing library system in accordance with the present invention;

20 **Figure 4** depicts a pictorial diagram illustrating the addition of a new library system to an existing library system in accordance with the present invention; and

25 **Figure 5** depicts a flowchart illustrating the procedure for adding a new library system to an existing library system in accordance with the present invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

1 The architecture of the present automated library
5 array **100** is illustrated in **Figure 1** and contains the
multiple independent robots **102** to enable the library
array **100** to concurrently manipulate multiple media
cartridges **105**. The library array **100** comprises a two-
dimensional array of media cartridge storage cells **103**
10 and media cartridge players **104** that are mounted in a
frame **101**. A system of rails **121-126** is used to guide
robotic pods **102** through all of the locations in the
array, which eliminates the need for any steering or
guide mechanisms on board the robotic pods **102**, resulting
15 in a reduction in the mass of the robotic pods **102**. The
rail system **121-126** also constrains the movement of the
robotic pods **102** into horizontal and vertical movements,
thereby simplifying the control algorithms for collision
avoidance that are required by a typical random moveable
20 object handling system based on horizontal, vertical and
diagonal degrees of freedom. The robotic pods **102** contain
a moveable carriage that is capable of transporting
robotic components, such as media cartridge pickers, bar
code reading devices, and other task oriented sub-units,
25 on the storage library rail system.

As shown in **Figure 1**, the frame **101** is designed to
receive a plurality of rows **151-154** of media cartridge
storage cells **103**, each of which is designed to house a
single media cartridge **105**. The media cartridge players
30 **104** are shown in an arbitrary location in a horizontal

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row 155 at the bottom of the frame 101, although the library array 100 can incorporate media cartridge players 104 at any location in the frame 101 to optimize performance. The robotic pods 102 are attached to the

5 frame 101 via horizontal guide rails 121-126, which serve to frame the media cartridge storage cells 103 and media cartridge players 104 on the top and bottom sides thereof. **Figure 1** shows an array of media storage cells 103 fully populated with media cartridges 105 of any

10 arbitrary type. The robotic pod guide rails 121-126 provide support of the robotic pods 102 in the vertical direction to oppose the force of gravity, and they also provide a meshing surface of suitable design to impart traction in the horizontal direction for motive transport

15 of the robotic pods 102. The robotic pods 102 each incorporate a drive means for propulsion in the horizontal direction along the guide rails 121.

Figure 1 also shows a plurality of vertical elevator assemblies 131-133 that enable the transfer of the

20 robotic pods 102 in the vertical direction. Multiple vertical elevator assemblies 131-133 are shown in **Figure 1** to exemplify the extensibility and redundancy of the invention. Each of the vertical elevator assemblies 131-133 comprise a set of vertical rails 142 that extend

25 substantially from the top of the frame 101 to the bottom of the frame 101. The vertical rails 142 support a plurality of elevator stations 140, each of which contain short horizontal rail segments 141A, 141B that are

30 identical in cross section to the main horizontal guide rails 121-126. The elevator stations 140 are held in

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suspension by a drive belt 143 which is made to wrap around a drive pulley attached to a vertical drive motor 113 that is located at the top of each elevator assembly 133. When a vertical displacement is required of any robotic pod 102, the vertical elevator 140 is scheduled to move in alignment to the appropriate level of rows 151-155 to allow transfer of the robotic pod 102 onto the elevator rail section 141A, 141B from the pair of horizontal rails 121-126 that are juxtaposed and abutting to the elevator rails 141A, 141B. Once the robotic pod 102 is located on the elevator station 140, the drive motor 113 is activated to transport the robotic pod 102 to a selected one of rows 151-155 and thence moves on to the pair of horizontal rails 121-126 that correspond to the selected row. Elevator assemblies 131-133 can carry more than one robotic pod 102 at a time by adding elevator platforms 140 to the elevator assemblies 131-133 or by extending the elevator platform length to accommodate multiple robotic pods 102 on a single elevator station 140.

Referring to **Figure 2**, a pictorial diagram illustrating the addition of an extension array to an existing library system is depicted in accordance with the present invention. The library system 210 depicted in **Figures 2A-2D** is comprised of several library arrays, similar to array 100 in **Figure 1**, which are arranged in banks. The track type architecture used with the storage arrays (depicted in **Figure 1**) allows the arrays to be connected within a single library system, wherein "roaming" robots can move between arrays by following

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connecting tracks, which trace cartridge locations and tape drives within the library system.

Figure 3 depicts a flowchart illustrating the procedure for adding an extension array to an existing library system. The procedure begins by selecting, via an operator control panel, the desired capacity scaling method, which in the present example is the addition of an extension array **220** onto an existing library system **210** (step **301**). The selection causes the control software to move robots away from the end of the rail location where the extension **220** is being added, and establishes the working space as a "keep-out" zone for the robots (step **302**). In this way, robots within the existing library system **210** can continue to operate in other areas of the library, without interfering with the addition of the extension array **220**. The operator panel is then used to set the relevant service door to an "open- eminent" state, thus alerting the control software to clear the robots from the work area (step **303**).

A door key is then used to unlock and open the service door (step **304**). The front cover assembly **211** is removed from the end of the library system **210** where the extension **220** is to be added (step **305**), and the extension array **220** is added to the existing library system **210** (step **306**). The robot guide rail segments of the extension array, e.g., rail **230**, are then fit to the guide rails on the existing library, e.g., rail **240**, thus connecting power to all segments (step **307**). A front cover assembly **221** is placed onto the end of the extension array **220** (step **308**). Additional robots can

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then be added as needed before the service door is closed (step 309).

After the physical components have been connected and the service doors have been closed, the operator
5 panel is used to notify the control software to initiate calibration and audit routine to bring the extension array on line with the preexisting library system (step 310).

When integrating new silos and arrays into an
10 expansionable library system, specific control algorithms are used to facilitate seamless integration. These control algorithms allow the library system to automatically detect new components and determine which resources are available to the system at any time. The
15 algorithms may rely on meta data, which is an inventory of resources available to an array at any given time and is maintained on a micro basis (short time periods). Examples of meta data include: what data storage devices are located within an array; where the storage arrays are
20 located; and how many robots are presently on the array and where they are located, which can change every few fractions of a second as robots move from one array to another. When adding new components to a library system, it is important to merge and integrate the meta data from
25 the different components. When a component is removed, the meta data is uncoupled. Meta data can be stored in NV-RAM, on a hard drive, or any other type of non-volatile memory storage within the arrays, which can hold its memory without power.

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By implementing the control algorithms described above, there is no need to shut down the library system 210 in order to add new physical components (i.e. extension 220). The host system 210 will automatically
5 detect these new components and incorporate their function and contents into ongoing system operations.

Referring to **Figure 4**, a pictorial diagram illustrating the addition of a new library system to an existing library system is depicted in accordance with
10 the present invention. **Figure 5** depicts a flowchart illustrating the procedure for adding the new library system. The procedure begins by selecting, via an operator control panel, the desired capacity scaling method, which in the present example is the addition of
15 an adjacent library 410 with a pass-through mechanism 420 (step 501). The selection causes the control software to move robots away from the end of the rail location where the adjacent library 410 is to be connected, and establishes the working space as a "keep-out" zone for
20 the robots (step 502). In this way, robots within the existing library system 400 can continue to operate in other areas of the library, without interfering with the connection of the adjacent library 410 and the installation of the pass-through mechanism 420. The new
25 library system 410 is then placed next to the original existing library 400 (step 503).

The operator panel is then used to set the relevant service door 402 to an "open- eminent" state, thus alerting the control software to clear the robots from
30 the work area (step 504). A door key is then used to

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unlock and open the service door where the pass-through mechanism is going to be placed between the library systems (step 505).

5 The operator should remove any robots from the work area where the pass-through mechanism is to be installed (step 506). The pass-through cover plates 401 and 411 are removed from the side walls of the libraries, thereby allowing the pass-through mechanism 420 access to both library systems 400 and 401 (step 507), and the pass-
10 through mechanism 420 is installed by means of the service doors 402 and 412 of either library (step 508).

The pass-through mechanism 420 allows cartridges to be passed between the adjacent libraries 400 and 410 by means of a bucket 421, which is driven about a pivot axis
15 423 by a motor 422.

The power and control circuits of the new adjacent library 410 are then connected to the cable harness of the mother library 400 (step 509). Unlike the addition of an extension array, the connection of adjacent
20 libraries does not require the operator to fit guide rail segments between the adjacent libraries. This is because each library is physically self-contained, except for the pass-through mechanism.

Once the libraries 400 and 410 are connected, robots
25 are replaced and/or added as needed and the service doors 402 and 412 are closed (step 510). The operator control panel is used to notify the control software to initiate calibration and audit routine to bring the new adjacent library 410 on line with the original mother library
30 system 400 (step 511).

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As with addition of extension arrays, by implementing the control algorithms described above, there is no need to shut down the mother library system 400 in order to add new library 410. The host system 400
5 will automatically detect the new library 410 and incorporate its function and contents into ongoing system operations.

The description of the present invention has been presented for purposes of illustration and description,
10 and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention,
15 the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

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